REMARKS

Claims 1-65 were previously filed in this patent application. Claims 1-8 and 66-67 are presented herewith for examination. Claims 9-65 are withdrawn. Claims 3-6 are as originally presented. Claims 1-2 and 7-8 are presently amended. Support for amended claims 1 and 2 is provided, for example, on page 9, lines 23-30, page 11, lines 4-5 and page 20, lines 19-20. In amended claim 8, the typographical error "radioactive" has been correctly rewritten as "radiative." Support is provided, for example, in claim 13 of the patent application. Support for new claim 66 is provided by claim 1, while support for new claim 67 is provided by claim 2. Applicant affirms that no new matter has been added to the patent application.

In accordance with the Examiner's remarks in paragraph 2 of the Office Action titled "Information Disclosure Statement," Applicant has enclosed herewith a copy of the text "A Practical Manual on the Monte Carlo Method."

Applicant thanks the Examiners for granting a telephone interview on July 10, 2006, and hereby requests careful reconsideration of this application in view of the following comments.

RESPONSE TO 35 U.S.C. § 112 REJECTIONS

Claims 1, 2 and 7

The Examiner rejected claims 1, 2 and 7 under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicant regards as the invention.

In pending claims 1 and 2, the phrase "substantially converge" denotes a value that sufficiently approaches the mathematically idealized convergence value. In non-trivial mathematical problems absolute convergence in finite time is often impossible. This principle is well understood in the field of optics. Applicant has included a definition of "substantial convergence" in the "Definitions" section of the specification, as set forth hereinabove.

In pending claim 7, the phrase "or a combination thereof" has been stricken.

During the telephone interview of July 10, the Examiners requested clarification as to Applicant's definition of "Ray Sets." Applicant has included clarifying language in the "Definitions" section of the specification, as set forth hereinabove.

Finally, during the above-referenced telephone interview, the Examiners also requested that Applicant indicate the existence of support in the specification for limitations containing the

phrase "and/or," recited in claims 1 and 2. Support is provided, for example, on page 7, lines 26-29 and page 35, lines 9-20.

For all of these reasons, withdrawal of the § 112 rejections is respectfully requested.

RESPONSE TO 35 U.S.C. § 102 REJECTIONS

Claims 1-7

The Examiner rejected claims 1-6 under 35 U.S.C. § 102(e) as being anticipated by Caflisch, et al. (US 6,714,620). The Examiner rejected claims 6-7 under 35 U.S.C. § 102(b) as being anticipated by an admission.

Applicant respectfully requests withdrawal of the § 102 rejections, as independent claims 1 and 2 have been rewritten to clarify that the invention pertains to:

> A **direct computational** method of algorithmically simulating the transportation of particles through a medium, comprising **non-stochastic** steps (for computing radiation transport).

A. Applicant's invention is patentable under § 102 since the claims recite novel physical subject matter that explicitly distinguishes Applicant's invention from Caflisch. Caflisch fails to disclose, teach, or fairly suggest the use of a direct, non-stochastic computational method. Rather, Caflisch describes the stochastic (non-deterministic) generation of particles "chosen at random by sampling."

Briefly, in a stochastic methodology, error from the ideal solution is introduced by the statistical uncertainties of various sampling processes. In the direct methodology of the present invention, error from the ideal solution is introduced by the assumptions embedded in discretization of variables and the geometric spatial, angular and energetic displacements such discrete variables introduce.

Although, Caflisch can use superposition of Monte Carlo values, the values fail to meet the operational conditions of the present invention. Stated otherwise, Caflisch is unable to solve problems with restrictions required for Invariant Imbedding. In particular, if one were to apply Monte Carlo to Caflisch in an attempt to obtain transport factors, the iterative aspect of the design would compound stochastic errors resulting in skewed asymmetric and unacceptable

answers. In contrast, Monte Carlo can be hybridized with the present invention, as recited in claim 4, to obtain particle distributions that are associated with raysets (*see* Fig. 7 Block 3). This rayset definition is not disclosed, taught or suggested by Caflisch in the patent's definition of beamlets. The present invention does not employ superposition of doses as described by Caflisch. Rather, the present invention is non-stochastic and is direct. Some advantages of the present invention over Caflisch include, for example:

1. The present invention is able to specify phase space differential initial conditions in any context (Fig. 7 Block 3) and obtain correct results. This is not possible with Caflisch for critical or supercritical systems.

2. The present invention is an efficient, cost-effective solution to problems in contrast to legacy and expensive traditional methods such as the Stochastic and Direct Boltzmann Transport Equation.

3. The present invention is able to perform a one-time setup calculation (Figs. 7 and 8) with no initial particle distribution information (Fig. 7 Block 3) and very little or no *a priori* problem information and quickly run problems with different initial conditions ("what-if calculations") to rapidly obtain numerous practical solutions.

4. As shown in Fig. 4, the invention is able to break the traditional input->process->output paradigm for solution of transport problems. This is particularly useful for automated processes that repetitively utilize "what-if" calculations. This is unattainable by Caflisch without detailed *a priori* information.

5. Multi-dimensional Imbedded Invariants can be used in connection with the present invention. This is to be contrasted with the existing art, where Imbedded Invariants can only be used in a single dimension. Furthermore, in the present invention the Imbedded Invariants need not be completely and totally invariant for operability.

B. <u>The present invention transforms a traditional boundary-value problem to an initial-value problem</u>**.** A boundary value problem is a mathematical problem in which conditions at geometric spatial boundaries are fully specified (such as beamlets in Caflisch) and transport occurs globally bounded in time until such time as all or most particle scores are tallied (as in Caflisch—the final tally dose distribution). Such designs can superimpose tallied results to directly obtain a final particle distribution from "pencil beam" methods in various schemes.

Such superposition occurs in one step, or in the case of a Green's function, often occurs simultaneously with the generation of a solution in an input->process->output paradigm while tightly constrained to the boundary-value global solution. The use of superposition as a one-step, rapid process that is not disclosed or suggested by Caflisch. Rather, Caflisch relies on Monte Carlo to provide input data for a fast pencil beam computation that is known in the art as "superposition." The present invention discloses a process that allows for pre-processing of generalized information without the requirement of foreknowledge of where the focus of radiation or initial distribution of radiation may be. Further, the present invention does not require any specification as to the generation of radiation once it is a simple initial value within the imbedded invariant context.

An initial value problem as described by the present invention is fundamentally different from those discussed by the Examiner in that rather than using scoring tallies for superposition and solution construction, the asserted references use transport multipliers that are tightly bound in time epochs (collision moments). This effectively relaxes boundary conditions.

For instance, one can use a partial current rather than a net current boundary condition. These time epochs relate to a physical quality that is geometrically and somewhat materially invariant, and hence are restricted in terms of time, but can be solved iteratively with initialization in terms of space. Such invariance is relaxed in the present invention (*see* page 31, lines 27-28 of patent application). The present invention is a fundamentally different approach to the solution of transport problems stochastically as well as to the solution of transport problems that retain the normal global time formalisms—for example, the Boltzmann Transport Equation ("BTE") and its myriad derivatives. An invariant imbedded technique is neither statistical (though data may be derived statistically) nor a direct means of solving the BTE.

As described in the present application, the mechanism of the invention uses an iterative process to reconstruct the full time integrated result associated with time epoch differentiated radiation transport interaction events. The initial value nature of the solution allows one to specify a plurality of initial value points without running out of memory. In the present invention, one must pay close attention to the restricted definitions of Integration Kernels and Transport Multipliers that fit into the imbedded invariant conceptual context. These are clearly restricted in time or generation or scattering moment, although acceleration in certain contexts (problem specific) can occur. These multipliers are clearly distinguished from final scoring

tallies, in contrast to Caflisch. In order to accumulate interaction tallies in the present invention, one must run an iterative calculation with a separate and distinct interaction model (Fig. 7 Block 5).

The present invention is solved in two separable phases. The first phase requires minimal or no foreknowledge of how particles will initially be distributed in the system. In subsequent solution phases, very fast solutions are created from any number of initial conditions, allowing multiple what-if scenarios. In this fashion, the present invention provides a practical multidimensional method for "Invariant Imbedding" through the use of computer memory.

The initial conditions with regard to beamlets in Caflisch require a thorough, total, and time epoch global or integral particle distribution description resulting in a particle distribution. In the present invention, the collision moments of source particles are separate, and hence each requires far less memory than any process disclosed in Caflisch. Considerable information regarding initial particle position and distribution of a plurality of particles is required in Caflisch. Caflisch clearly relies on stochastic methodology or pencil beam, as described in the '620 patent at column 27, lines 14-24. Thus, there is no basis for comparing this methodology with the present invention, which teaches away from Caflisch.

The nature of initial values and defined scattering epochs in the present invention greatly reduces its storage requirements and its setup time (*see* Fig. 17 Monte Carlo comparison). Moreover, the present invention advantageously avoids errors associated with stochastic variance. Further advantages of the subject invention over Caflisch include distributed error control, initial value setup processing that enables fast evaluation of "what-if" scenarios with arbitrary initial beam or radiation distribution scenarios, the ability to make changes to material compositions while fairly accounting for the change in final answers, and the ability to use the present invention with comparatively smaller machines.

<u>It would not have been obvious to modify Caflisch's non-deterministic process in accordance with Applicant's direct, non-stochastic computational method, as defined in revised claims 1 and 2. Doing so would be entirely counter to the stated intentions and process design requirements of Caflisch to generate final particle tallies relating to dose distribution from beamlets, in a random manner.</u>

Furthermore, raysets are fundamentally different from beamlets. A beamlet, as discussed in Caflisch, intrinsically includes initial position information. A rayset according to the present invention is a line or a set of ray lines (or solid angle sets) upon which or within which radiation propagates from one side of a phantom to another and beyond. If a particle of radiation is a train, a beamlet would be the station and the rayset the track. Beamlets have tracks, raysets do not require stations. These are related but very different concepts. In Caflisch, radiation must propagate from fixed stations—in the present invention, the station can be anywhere along the track from whence radiation emanates.

C. The references in Caflisch bear no resemblance to the transport multipliers of the present invention. The values referred to in Caflisch would more properly fall into the category of tallies, as defined in the present invention. This is a fundamental distinction between Caflisch and the present invention; these terms do not correlate upon inspection of the definitions, the mathematical requirements, and the limitations of Applicant's claims 1 and 2, which require separate transport and interaction processes in an iterative context.

In the present invention, applying transport multipliers (*see* application "Definitions") from a first plurality of voxels to a second plurality of voxels means directly computing, within a collision moment or time epoch, the restricted time collision transport from voxels to voxels. When a photon arrives from some location and scatters in an epoch it is tallied. All such first collision moments are tallied as described in the present invention in a sweep. One then proceeds through an interaction model that describes where the scattered photons will go. Once the scattered photons are distributed, one can move to electrons and deposit doses (or simultaneously accumulate). Comparison of the computed dose distribution to the final dose distribution is completed at the end of the process. This is due to the fact that detailed interaction moment by moment measurements far exceed the existing measurement technology.

How then could Caflisch, which correlates to a measured dose owing to the fact that the solution is complete (i.e., all the way to dose), be compared with the present invention in which the intermediary values described are incalculable and immeasurable? Collision moment and Eigenvalue epoch moment intermediary values are not currently measured with any sort of precision, and given the Heisenberg Uncertainty Principle that covers time-frequency domain reality, these values are probably outside the scope of accurate measurement.

D. The present invention is not Monte Carlo, and it is non-stochastic. The invention does not rely on Monte Carlo to achieve the results presented in Applicant's patent application. As an option, Monte Carlo *may* be used in the present invention; however, it must be restricted to a context not anticipated by the prior art.

Caflisch clearly describes an input->process->output paradigm Monte Carlo Stochastic solution with superposition convoluted with measurement correction for direct dose computation. In essence, this is a technique for deriving superposition dose distributions and reconciling such distributions with measurements. It is not, however, a technique for quickly computing doses with a distinct setup phase and subsequent multiple scenario what-if processing, except as it enables improvement of pencil beam prior art.

Figure 17 of Applicant's application shows a comparison between the direct solution of the present invention and Monte Carlo (GVMP). As shown, the present invention is several times faster than Monte Carlo, even for an input->process->output paradigm. This superior result is obtained because the direct method of the present invention requires the discretization of variables introducing discrete errors.

The present invention is a direct solution as opposed to a stochastic solution. Only claim 4 of Applicant's patent application references Monte Carlo as an optional means for computing the parameters of the invention. However, optional Monte Carlo can only be used in accordance with the mathematical restrictions of Applicant's invention; namely, to create transport multipliers that can be used in an iterative, Imbedded Invariants context. Even in this limited context, Monte Carlo has numerous shortcomings, particularly with respect to the introduction of stochastic errors that are propagated and compounded during iteration.

The preferred embodiments of the present invention include ray tracing and point to point methods for computing transport multipliers. Monte Carlo is optional and must be carefully limited if it is used (in order to fit Imbedded Invariant time epoch or collision moment contexts). The present invention does not require, nor does the preferred embodiment utilize, Monte Carlo or stochastic processes except as a possible option for the generation of fundamental constant physical input data.

In Caflisch, final particle tallies relating to dose distribution are generated from beamlets. However, in the present invention the Caflisch dose tallies are of no value. Instead, one must compute fundamental transport multipliers as described in Applicant's patent application and as

restricted in accordance with the preceding discussion. This differentiates photon, electron transport, and dose deposition as separate processes in the present invention. It further restricts one or more collision moments for invariant qualities.

Caflisch describes a measure adjustable calculation using Monte Carlo. The methods of Caflisch and the present invention, respectively, are entirely dissimilar. Certain definitions, at first glance, may appear similar. However, a reading of the '620 patent (see, e.g., column 28, lines 43-45 and column 38, lines 50-67) discloses that Caflisch's process relies on Monte Carlo statistical convergence; whereas the present invention teaches Eigenvalue initial value invariant imbedding convergence. These methods are completely and thoroughly unrelated.

For all of these reasons, Caflisch cannot anticipate Applicant's claims 1-7. Applicant respectfully requests allowance of amended independent claims 1-2 and of claims 3-7, which depend therefrom. The pending claims recite a new principle of operation that is not disclosed, taught or otherwise suggested by Caflisch. The revised claims clearly distinguish Applicant's invention from the patented references. Accordingly, withdrawal of the § 102 rejection is hereby requested.

RESPONSE TO 35 U.S.C. § 103 REJECTIONS

Claims 7-8

Claims 7-8 were rejected under 35 U.S.C. §103(a) as being unpatentable over Caflisch, et al. (US 6,714,620) in view of Llinas, et al. (US 2003/0144432 A1). Applicant respectfully requests withdrawal of the § 103 rejections in view of the comments and revisions to independent claims 1-2, as set forth hereinabove.

Furthermore, if one were to apply Caflisch and Llinas to a problem involving critical or supercritical particle multiplication (e.g., traditional Sturm-Louiville in a nuclear reactor), the methods of Caflisch and Llinas, singularly and in combination, would fundamentally not work. This is because Caflisch and Llinas do not distinguish time epochs and/or collision moments to attain Invariant Imbedding properties. Where would one attain the initial particle distributions in Caflisch? Caflisch describes specific sampling. As such, there is nothing to measure or adjust;

thus the transport multipliers of Caflisch are meaningless, because they are overwhelmed by a critical or supercritical system.

Conversely, in the present invention, one simply applies the defined criteria for a transport multiplier to, for example, the absorption and fission processes as invariant collision moments. Scatter, especially fast neutrons within a reactor, is usually unaffected by multiplication (ratio of U235/U238, e.g., in a uranium fueled nuclear reactor). The present invention is fully operable with critical and supercritical systems because the boundary of time is thorough in the transport multiplier, and time epoch results are accumulated naturally as part of the iteration scheme.

In a similar vein, it is important to consider how one would apply Caflisch and/or Llinas, beyond straight-forward prior art Monte Carlo simulation, to a realistic boiler heat transfer problem or to a system in which the scattering medium changes. Both Caflisch and Llinas fail in these instances. In contrast therewith, in the present invention, the time epochs are strictly controlled in accordance with the transport multiplier and integration kernel definitions. Accordingly, one can vary material compositions, densities, etc., and still utilize the precompute capabilities of the present invention to obtain tremendous speed improvements. Furthermore, in the present invention, the attenuation of thermal radiation results in an integration kernel. One may then create a grid system of voxels and compute single thermal interaction parameters along the rayset tracks of thermal radiation from a plurality of voxels to a plurality of terminal voxels. Lastly, the thermal distribution is obtained through iteration. If the sources of heat change in the present invention, rapid results can be accurately attained.

Conversely, if Caflisch and/or Llinas is applied, the system would have to be simulated with the new input distribution, as one is bound to the input->process->output paradigm. For instance, let us assume that Caflisch and Llinas are used in real-time protocol ("RTP") to break the input->process->output paradigm by defining beamlets (as opposed to raysets) without prior knowledge as to target (as in Fig. 7 of the present invention) in order to diffuse radiation upon a cubic phantom. Further assume that the phantom is a $20 \times 20 \times 20$ system of voxels. Lastly, assume the standard 100 cm ssd and use of only three of six possible sides to transmit beamlet information to the voxels. To cover all angular possibilities without a prior knowledge of where the target is in the $20 \times 20 \times 20$ cm^3 system would require approximately the following number of rays on a 1×1 cm initial beamlet resolution basis:

With only three sides, there are approximately $100 \times 100 \times 3 = 30{,}000\ cm^2$ from which to center the beamlets.

To compute without *a priori* target knowledge, there are more than 20×20 back projection axis angle centers per beamlet or $30{,}000 \times 400 = 1.2e7$ initial beamlet conditions for problem coverage (the back layer projection from each beamlet starting point should at least be covered). As such, 12,000,000 expensive Monte Carlo simulations are required to provide the initial conditions for Caflisch's and Llinas' "setup" to be comparable to that of the present invention. This process would continue in perpetuity.

The present invention will now be considered in an identical context. In the present invention, a problem can be initiated anywhere; therefore, 1.2e7 beamlet initial conditions and specification of the ssd are unnecessary! The scatter process can be started by relating initial radiation to raysets (trains to tracks, *see supra*) and coupling voxels on a first collision basis. The present invention employs voxel to voxel coupling and LVG to LVG coupling. With multiple resolution, a $20 \times 20 \times 20\ cm^3$ system can easily be accommodated in several GB of computer RAM. Furthermore, the present invention is able to quickly process approximately $8000 \times 8000 \times$ #energy groups = $6.4e7 \times$ #e group setup calculations.

Although this number is extremely large, the present invention is comparable to or faster than a single Monte Carlo computation (of which Caflisch and Llinas would require millions).

The present invention utilizes an iterative calculation to process further scatter moments as particles collide in the direct methodology. As an option, once the calculation is set up, the process of the present invention can be run for 1.2e7 starting points in order to generate data. This, of course, may be dispensed with, as the invention runs very fast.

In the Caflisch example, a very coarse 1×1 resolution was obtained due to the beamlet restriction. In the present invention, one can start with a raytrace distribution from anywhere and simply relate the initial particles to raysets that enter the present invention phantom. This means that in this context, after waiting endlessly for Caflisch to compute initial beamlets positions (since there is no *a priori* knowledge of targets, etc.), the dose superposition answers are relatively inaccurate compared to the present invention. In view of the foregoing, it is clear that

Caflisch and Llinas, both singularly and in combination, cannot render Applicant's invention obvious.

Caflisch and Llinas fail to disclose, teach, or in any way suggest the use of ray tracing for transport factors, as defined by Applicant's invention. Rather, Caflisch and Llinas rely on Monte Carlo for transport factors. In addition, Caflisch and Llinas do not describe or even suggest the design requirements and mathematical conditions imposed on transport factors by the present invention. The present invention utilizes real numbers, rather than integers, to relate tissue property changes. So too, the geometries in the present invention are known, even when they are irregular.

The features of Applicant's invention are nonobvious and hence patentable under § 103 since claims 7-8, based on amended claims 1-2, recite novel physical subject matter that explicitly distinguishes Applicant's invention from those of Caflisch and Llinas. For all of these reasons, Applicant respectfully requests withdrawal of the § 103 rejection.

NEW CLAIMS 66-67

Applicant respectfully requests allowance of claims 66-67, which recite a new principle of operation that is not disclosed, taught or suggested by Caflisch or Llinas, singularly or in combination. Allowance of the subject matter of claims 66-67 is therefore requested of the Examiner.

CONCLUSION

Applicant's invention reveals a new and unexpected principle of operation that is not taught, disclosed or in any way suggested by Caflisch, Llinas, or any combination thereof. The novel features of Applicant's invention which effect this new principle of operation are clearly recited in Applicant's pending claims 1-8 and new claims 66-67. Therefore, Applicant submits that claims 1-8 and 66-67 define patentably over the prior art and should be indicated allowed.

Applicant believes all of the presently pending claims are in condition for allowance. Accordingly, entry and careful consideration of this Response and an early indication of allowance is hereby requested. If the Examiner believes there is any issue that could be resolved

by a telephone conference or a personal interview, the Examiner is respectfully requested to contact the undersigned at the telephone number listed below.

Respectfully submitted,

Date: July 11, 2006

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